**Introduction**

One of the pressing problems of modern bone reconstructive surgery remains the issue of filling in the formed defects. Bioengineering is a rapidly developing branch of the industry. To date, there are many options – from autobone to xenoimplants, while the material used must meet the following properties: bioresorbability (dissolution in the body environment), osteoconductivity (to be a matrix for newly forming cells), osteoinductivity (to regulate the process of transition to osteoblasts), biocompatibility (structural similarity to bone), provide mechanical strength, be easy to use, safe (biosafety, also not to be toxic) [1]. Synthetic biopolymers have quite high requirements, and, thus, native bone remains the only material that meets all the declared characteristics.

There has been a steady increase in restorative interventions in odontology. It is known that our teeth, in addition to the aesthetic component, perform a number of important functions: they participate in the mechanical processing of food, in the formation of sounds, in supporting facial muscles, etc. During implantation operations, bone grafting is necessary to create a sufficient thickness of the alveolar bone, which will provide reliable stabilization [2]. Indications for this type of treatment are not only complete tooth loss, but an increase in additional volumes of bone tissue may also be required during removal, accompanied by resorption during the first 3-6 months after extraction, leading to a loss of bone width by 29-63%; periodontal diseases; after jaw injury [3].

The incidence of primary vertebral tumors is 0.2% of all cancers [4], however, the spine accounts for 70% of all bone metastases: lung, breast and prostate cancer, malignant melanoma, tumors of the kidneys, gastrointestinal tract, bladder, thyroid gland and colorectal tumors [5]. In orthopedics, there is a need for bone and plastic materials not only in oncovertebrology, but also in the treatment of false joints, non-healed fractures, during anterior and posterior spinal fusion [6].

Special requirements are imposed on a bone implant when replacing defects in the treatment of chronic osteomyelitis, the prevalence of which is 10-25% in the structure of diseases of the musculoskeletal system, due to the fact that in addition to filling the postnecrotic cavity itself, the material must have antimicrobial properties [7, 8]. The latter is achieved by exposing bone allograft in an antibiotic solution [9].

With all the above-mentioned sections of medicine and the described nosologies, much attention is paid to the preparatory stage, which includes the search for the implant itself, its preparation and preservation. The osseointegration-reparative process in the human body, which takes 4-8 months, depending on the volume of interventions, is the most difficult issue of regenerative medicine, since its success depends on many factors, including the stage of bone crushing (grinding method, particle size, absorption-cumulative ability of the biocomposite when using additional solutions, etc.) [9, 10].

**Purpose:** to identify and describe the main types of developed bone grinders, systematize and present a classification of devices with this function.

**Search methodology**

First of all, we would like to note that there are no clear criteria recommendations in the scientific community for conducting a literary review of medical devices, and there is a disparity in the methods of their assessment both in international sources and in Russian-language data [11, 12].

The search was carried out on the websites of medical devices and all patent databases, descriptive characteristics of the devices were taken from the official websites of manufacturers or distributors, formulas and abstracts of inventions. When searching the information network, the following keywords were used: "crusher", "shredder", "Crusher", "mill", as well as a combination of these nouns with the adjectives "bone", "orthopedic", "medical", "electric". The inclusion criteria were devices during the operation of which the process of grinding bone or solid materials takes place (5 and higher according to the Mohs classification). All industrial options used in the mining, processing, metallurgical, construction, and agro-industrial sectors were excluded.

We could divide the found types of products into the following groups: by mechanism; by the method of grinding; by the size of the particles obtained; by the field of application; multiple uses, etc. It was decided to present the descriptive part of the suitable devices in the "results", and transfer the comparative component to the "discussion".

**Information search results**

Grinding is the process of separating solids into parts to the required size by mechanical action with the formation of new surfaces [13]. The following grinding methods are known: by crushing, splitting, breaking, cutting, sawing, abrasion, constrained and free impact [14]. During these processes, grinding classes are conditionally distinguished, which depend on the size of the initial and of course formed particles. Crushing is divided into large, in which the size of the pieces before grinding is 1000 dh, mm, and after – 250 dk, mm (index "h" indicates the size before grinding, index "k" – after); medium (from 250 dh, mm to 20 dk, mm) and small (from 20 dn, mm to 1-5 dk, mm). The second class of grinding is "grinding", which in turn is divided into coarse, the initial size of the raw material is from 1-5 dh, mm, and after that it is 0.1-0.04 dh, mm; medium (from 0.1-0.04 dh, mm to 0.005-0.0015 dh, mm); thin (from 0.1-0.04 dh, mm to 0.01-0.05 dk, mm), colloidal (from 0.1 dh, mm to 0.001 dk, mm) [13].

2 variants of bone mills from Medisporex (Pakistan) were found, while the first of them consists of a mortar with a diameter of 50 mm and a pestle (D=40 mm) (Fig. 1), the second resembles the classic "garlic mill" (Fig. 2) [15, 16]. A bone mill with a handle, article NK-MI2 from Ul Amin (Pakistan), and a mill from Asa Dental (Italy) have a similar structure [17, 18]. In these three devices, grinding occurs when the valve is turned. Mechanical mortars are crushed by pressure, the material is fed into the area between the mortar and the pestle, bone chips are obtained in the size of 0.5-1 mm.

The third type of hand mills manufactured by Mr. Curette Tech, South Korea (Ø38 x 72 mm; drum volume 3.5 cm3) grinds any type of bone into a homogeneous bone crumb of 1- 1.5 mm in size (Fig. 3) [19].The SD-BM bone mill from Surgident (South Korea) has a similar structure. It consists of a body, a metal grille, a handle, and a metal "pusher" with sharp teeth is also included. After installing the descriptor, you need to scroll the handle, then disconnect the lid from the case and remove the remnants of bone chips from the grill. The size of the resulting grinding is 0.1 mm [20].

The next model from Innomed (Savannah, Georgia, USA), InnoBoneMill 8205 resembles a "meat grinder" with its external design, consisting of a 30.5 cm long body, two cutting cylinders (hole diameter 3.2 mm / 5 cutting rows, the second has a hole diameter 4.2 mm / 4 cutting rows), a handle, a pressure block and a desktop the clamp. Grinds bones of various densities by cutting (Fig. 4) [21].

Similar also to the previous version in appearance, "A mill, in particular for grinding bone, as well as a drum equipped with cutting elements used in a mill" (full name of patent No. WO1998034491 dated 08/13/1998) consists of a body and a drum rotating inside the body and equipped with cutting elements that are formed by local thickenings of the drum wall. The authors claim that the drum can be replaced with another one to produce bone chips of different sizes [22].

Pulse crushers from IKA (Germany) are known to have a grinding chamber that grind hard, oily and aqueous samples, while they are equipped with a digital timer, controlled using a keyboard, characterized by low noise, easily replaceable beater/cutting for various applications, grinding occurs due to cutting and impact (Fig. 5) [23, 24].

A simple bone crusher (CN210447218 from 05.05.20, China) consists of a cylindrical container with a diameter of 30 mm in the lower part and a height of 50 mm, in the side walls of which there are symmetrically open four round holes (two pairs of through, evenly distributed in the front, rear, left and right directions); a fixing unit containing fixing plates and a handle; a cutting component consisting of an overhead plate with a set of knives, 20 mm blades facing the bottom of the converter tank and a rotating handle; a pushing part (includes a rod, pressure plates). After fixing the bone mass at the bottom of the container, a rotating handle is activated, after which the cutting part of the device conveniently converts the rotational force into a vertical downward one. During the "cutting" (grinding method), 2-3 mm square particles are obtained [25].

A craniofacial bone mill (WO2000053128 dated 09/14/2000, Canada) was found, having a lid and base, a disk, a grinding part made of a shaft and a cutting blade. After placing the material in the chamber, it is necessary to connect the device to an external power source (for example, a dental drill or other drilling tools can be used, preferably with a speed in the range of 500 to 5000 rpm with a torque of 60 to 100 newton/m) through a shaft that will rotate and lead to The cutting component is activated, which moves axially relative to the pieces of bone on the disc. Bone particles ranging in size from 50 to 500 microns (0.05-0.5 mm) can be obtained [26].

Orthopedic/vertebral bone mill (US20110172671 dated 07/14/2011, USA) containing a vessel consisting of a bowl-shaped lower base and a lid with a hole, and a grinding tool including an elongated rod passing through the hole in the roof along the axis, with a cutting blade mounted on the rod inside the chamber, and rotating by means of a drive device such as a drill (preferably rotation from 500 to 3000 revolutions per minute with a torque of up to 100 newtons/meters) [27].

The electronic device for grinding bone (CN206526080 dated 09/29/2017, China) includes a rack unit consisting of a handle, a rack and a lower protective plate, a grinding unit consisting of a head, and a control unit [28].

The modular bone mill for converting bone raw materials into bone chips (EP4162904 dated 04/12/2023, Stryker corp) consists of a base and cutting modules, including a shell with a removable mechanism, motor, sensor. The cutting element is located in the shell between the inlet through which the bone material is introduced into the shell and the outlet through which the bone chips are removed into the adjacent removable trap tray. The method of grinding is cutting [29].

The final version of the review will be the Cryomill laboratory ball vibration mill (Germany), consisting of a housing, grinding cups made of zirconium oxide of various sizes with screw caps, balls and a liquid nitrogen supply system. It is used for samples with a volume of up to 20 ml, grinding occurs as a result of the powerful action of impact and friction [30].

**Discussion of the results**

The first described mechanical mills have compact dimensions and a simple design, are completely sterilizable, but the volume of raw materials obtained is limited per unit of time, therefore they are applicable only in orthodontics. "Meat grinders" (Fig. 4 and the invention according to patent WO1998034491) are used for grinding bones of different densities, securely fastened with a table clamp, easy to use, easily disassembled, fully autoclavable, while the "patent" version, as stated by the authors in the description, can be used for grinding other materials such as wood and plastic. Their work requires the physical strength of the operator. Despite the electrical control, option No. 5 is not sterilizable, therefore it is applicable only in laboratories for conducting experiments, but not in operating rooms.

The "simple bone crusher" (CN210447218) has compact dimensions, each part is sterilizable, it can be used separately without an external power source, the grinding method is cutting. The scope of application is not specified, but given the size of the device itself (30\*50 mm) and the resulting 2-4 mm particles, we assume that it can be used in dentistry.

The "craniofacial" (WO2000053128) and "vertebral" (US20110172671) mills require an electric source to operate, while more careful observance of the rules of asepsis and antiseptics is necessary to connect additional devices.

"Electronic device for crushing bone" (CN206526080), although it contains "crushing" in its name, but upon detailed study of the description it turned out that this is not a device for preparing an implant, but a device for "snacking" the bones of the skull or vertebrae during surgery.

CryoMill, as a result of cooling, grinds materials such as: soil, chemicals, fabrics, hair, wood, sewage sludge, bones, plastics, oilseeds, paper, plants, tablets, textiles, animal feed, wool, etc. Hypothetically, we assume that the grinding cups can be sterilized and there is a possibility for use in the operating room, but it is necessary to comply with the rules of asepsis and antiseptics, as well as a place to store the device itself and the liquid nitrogen supply system. When working with this device, it is necessary to observe operational safety techniques.

**Classification of medical devices for bone crushing with interpretation:**

**1) By application area:**

• Dentistry

• Maxillofacial surgery

• Vertebrology

• Orthopedics

The musculoskeletal system of an adult consists of 205-208 bones, almost each of which may require filling in a defect as a result of one or another nosology related to the above sections of clinical medicine.

**2) By mechanism:**

• Mechanical (manual)

• Automated/ electric

• Semi-automated

This point is about the nature of the force used to operate mills, we have described enough options for the first two, while we did not meet the third one when searching, but we do not want to limit the flight of engineering thought.

**3) According to the method of grinding:**

• by crushing,

• splitting,

• breaking,

• cutting,

• sawing,

• abrasion,

• cramped and free kick,

• press

• combined.

To complete the classification, all possible grinding methods are listed, which are used not only in bone mill variants, but also for all solid particles.

**4) According to the main grinding mechanism:**

• Cutting tools

• Knife blades

• Cyclonic

• Disk drives

• Rotary

• Spherical planetary

• Cross drums

• Jaw crushers

This division indicates the prevailing technical component in the devices.

**5) According to the grinding class:**

• Crushing (large, medium, small)

• Grinding (coarse, medium, fine, colloidal).

They also decided not to limit the grinding class, they gave all possible options from the literature.

**6) By device name:**

• The mill

• Shredder

• Crusher

We mean that when using "mills", we will get smaller particles than when using "crushers", but it is worth noting that the division is quite conditional, because after conducting an information search, we were convinced that the authors and manufacturers do not lay deep logical understanding in the name, more often using the classic version of "mill".

**7) By the name of the resulting particles:**

• Bone meal/powder

• Bone chips

• Bone shavings

This gradation is associated with an associative series when using a visual analyzer, while bone "flour" as such may not be used in the clinic, nevertheless, we will not limit the possibilities of using such a fraction in the experiment. "Chips" are appropriate for bone grafts in orthodontics, and "chips", for example, when filling large bone defects of tubular bones. At the same time, it is worth noting that there are no studies that would assess the relationship of osteoreparative processes to particle size.

**8) According to the conditions of use:**

• Laboratory

• Operating rooms

This criterion is based on the possibility of autoclaving devices, while admitting the possibility of separation into "sterilizable" and not "sterilizable", but we understand that there are options when the part of the device directly in contact with the transplant can be autoclavable, but the body itself with a technical filling is not, for example, a cryomill.

**Conclusion**

Thus, having considered all the variety of options presented, it is possible to formulate technical requirements for bone mills used during operations: compactness of the body itself, sterilizability, replaceable cutting part of the device and its easy-to-replace wear, since bone belongs to a sufficiently durable material, variability in the size of cutting blades to obtain different grinding classes, ease of use, the easy removal of bone chips from the walls of the device (relevant in dentistry, since most often an auto-material is used, to reduce the volume of bone sampling from the patient himself), an automated drive (when it is necessary to fill in large defects to reduce the operation time), a small number of components of the device itself (we take into account the time of assembly and disassembly, as well as the time and amount of space occupied during sterilization in installations).

It is worth noting that it is necessary to develop recommendations for conducting reviews of medical devices, since there is no information about the descriptive characteristics of devices in classical article search databases, therefore, the search was carried out on manufacturers' websites and patent databases.